Chandra Localizations of LMXBs: IR Counterparts and their Properties

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Abstract. We present new Chandra observations of the low mass X-ray binaries (LMXBs) X1624−490, X1702−429, and X1715−321 and the search for their Infrared (IR) counterparts. We also report on early results from our dedicated IR survey of LMXBs. The goal of this program is to investigate whether IR counterparts can be identified through unique IR colors and to trace the origin of the IR emission in these systems.

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INFRARED PROPERTIES OF LMXBs

Traditionally, LMXBs have been studied in the optical and UV part of the spectrum. In order to explore the IR properties of LMXBs and to investigate the most heavily absorbed sources in the Galactic Bulge, we are undertaking a dedicated IR survey of all LMXBs. In addition to our own observations, we have also searched the literature for published IR magnitudes for these sources. For the brightest LMXBs in fields with moderate crowding, we extracted J, H, and K magnitudes from the 2MASS database. Selected early results from our survey are summarized in Table 1 below. Most of the observations were obtained with the 1.5m telescope at CTIO. Photometry was performed with DAOPHOT II and standardized magnitudes were derived through comparison with 2MASS.

Figure 1 shows the position of the individual LMXBs in the IR color-color diagram (filled circles). Open circles indicate multiple measurements of the same sources. Also shown are the main sequence and giant branch tracks. The intrinsic variability of the LMXBs limits the predictive power of the IR colors (see e.g. Sco X−1). A few sources reveal the contribution of a giant mass donor. X1608−52 and X1636−536 appear to show very unusual colors. These are some of the faintest sources we measured and require deeper observations to confirm our photometry.

Figure 2 shows the positions of the individual LMXBs in the IR color-magnitude diagram (note that apparent, not absolute, K magnitudes are plotted). The symbols are the same as used in Figure 1. For comparison, we also include the location of field stars from a representative Galactic Bulge field (small filled circles). The different branches visible in the color-magnitude diagram distinguish different types of stars. The first branch, roughly up to $J-K=1.8$, corresponds to nearby main sequence stars, while the clump of stars around $J-K=2.0-2.5$ represents a superposition of giant stars

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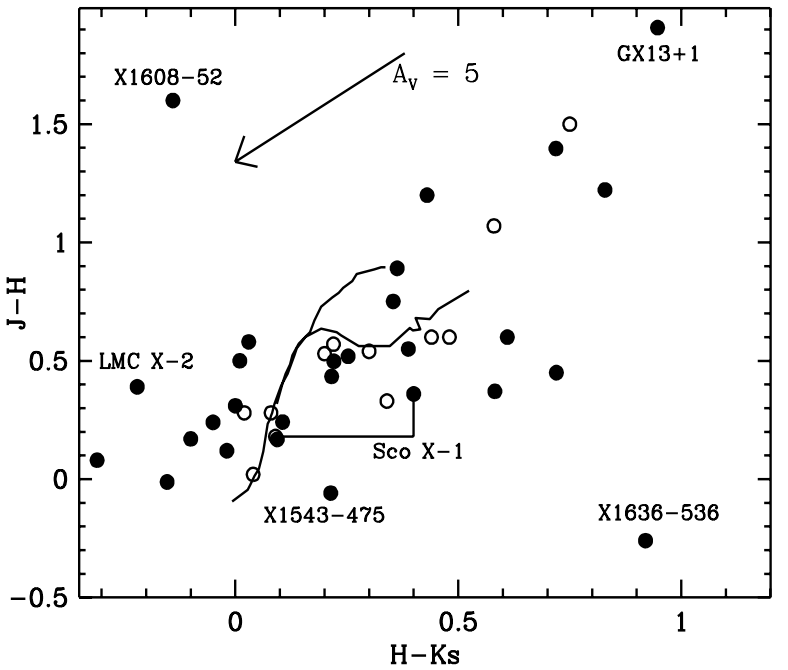

FIGURE 1. IR color-color diagram for LMXBs. For details, please see text.

with different values of extinction and distance. The LMXBs appear to preferentially cluster in an almost vertical strip around $J-K=0$. GX 13+1 stands out as a remarkably red source.

CHANDRA LOCALIZATIONS

X1624−490 and X1702−429

We observed X1624−490 on 2002 May 30 and X1702−429 on 2003 June 19 with the Chandra HRC-I for 1 ksec each. In the X1624−490 data set, a single bright source is detected at the center of the 30'×30' field. The best position is 16:28:02.825 −49:11:54.61 (J2000) with the nominal 0.6" positional uncertainty. In the X1702−429 data set, the X-ray binary is the only source detected. Our best localization gives 17:06:15.314 −43:02:08.69 (J2000).

We also obtained deep Ks band observations of each source at the ESO NTT with SOFI and the CTIO 4m telescope with ISPI, respectively. A single, faint ($Ks = 18.3 \pm 0.1$) source is visible inside the Chandra error circle of X1624−490, and we propose this source as its IR counterpart. For X1702−429, a $Ks = 16.5 \pm 0.07$ source is visible

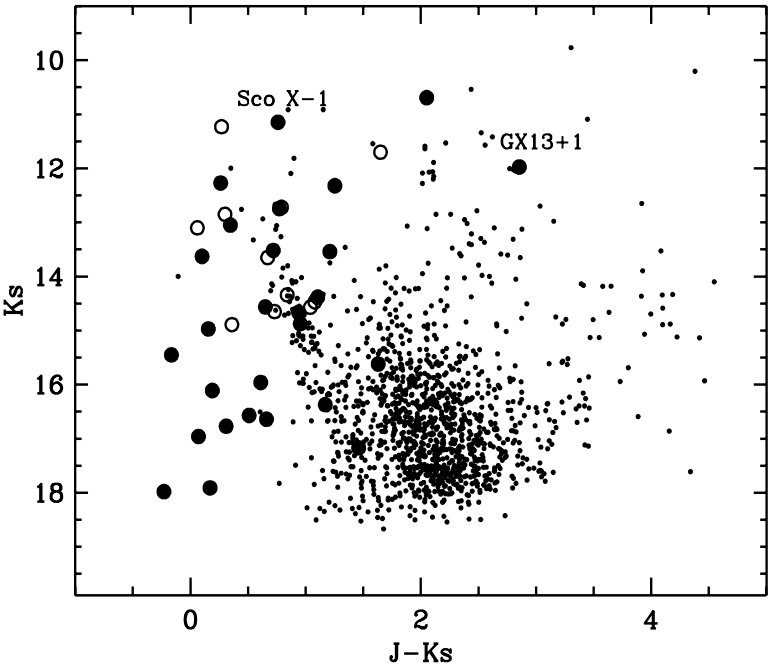

FIGURE 2. IR color-magnitude diagram for LMXBs. For details, please see text.

at the edge of the Chandra error circle. The brightness of both counterpart candidates is comparable to that of other low mass X-ray binary IR counterparts when corrected for extinction and distance. For details, please refer to Wachter et al. 2005, ApJ, in press.

X1715−321

X1715−321 is a poorly studied burster and transient at a distance of 5-7 kpc. We obtained a 1 ksec HRC-I observation of the source in an effort to detect its quiescent counterpart. No source was detected in the observation, placing an upper limit of 2.8×10^{-14} ergs cm^{-2} s^{-1} for the quiescent flux from this source.

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TABLE 1. IR Observations of LMXBs

Source	K	$J-K$	$H-K$	$J-H$	Ref.
LMC X−2	17.910	0.170	−0.220	0.390	this work
X0614+091	16.370	1.170	0.720	0.450	this work
X0620−003	14.383	1.105	0.354	0.751	2MASS
	14.470	1.080	0.480	0.600	this work
X0748−676	16.960	0.070	−0.100	0.170	this work
X0921−630	13.518	0.719	0.221	0.498	2MASS
	13.650	0.670	0.340	0.330	Lit.
Cen X−4	14.663	0.938	0.388	0.550	2MASS
	14.570	1.040	0.440	0.600	this work
Cir X−1	10.692	2.051	0.829	1.222	2MASS
	11.700	1.650	0.580	1.070	Lit.
X1543−475	14.890	0.360	0.080	0.280	this work
	14.970	0.155	0.214	−0.059	2MASS
X1550−564	15.620	1.630	0.430	1.200	this work
X1556−605	17.980	−0.230	−0.310	0.080	this work
X1608−522	17.170	1.460	−0.140	1.600	this work
Sco X−1	11.147	0.760	0.400	0.360	2MASS
	11.230	0.270	0.090	0.180	this work
X1636−536	16.640	0.660	0.920	−0.260	this work
X1655−40	12.744	0.772	0.253	0.519	2MASS
	12.720	0.790	0.220	0.570	this work
Her X−1	13.628	0.101	−0.019	0.120	2MASS
	13.100	0.060	0.040	0.020	this work
X1658−298	16.570	0.510	0.010	0.500	this work
GX 349+2	14.563	0.650	0.216	0.434	2MASS
	14.650	0.730	0.200	0.530	this work
	14.340	0.840	0.300	0.540	this work
GX 9+9	16.110	0.190	−0.050	0.240	this work
GX 1+4	7.979	2.116	0.719	1.397	2MASS
	8.060	2.250	0.750	1.500	Lit.
X1735−444	16.770	0.310	0.000	0.310	this work
GX 5−1	13.540	1.210	0.610	0.600	Lit.
GX 13+1	11.974	2.855	0.947	1.908	2MASS
J1819.3-2525	12.270	0.262	0.094	0.168	2MASS
	12.850	0.300	0.020	0.280	this work
X1822−371	15.450	−0.165	−0.153	−0.012	2MASS
Aql X−1	15.960	0.610	0.030	0.580	this work
X2023+338	12.321	1.254	0.363	0.891	2MASS
X2129+470	14.873	0.953	0.582	0.371	2MASS
Cyg X−2	13.049	0.347	0.106	0.241	2MASS

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